

CLAIMS

1. A laser processing method for irradiating an object to be processed with a first laser beam while converging the first laser beam with a lens such that a converging point is positioned within the object, and forming a modified region within the object along a line to cut in the object; the method comprising:

a displacement acquiring step of irradiating the object with a second laser beam for measuring a displacement of a main surface of the object while converging the second laser beam with the lens, and acquiring the displacement of the main surface along the line to cut while detecting reflected light reflected by the main surface in response to the irradiation; and

a processing step of emitting the first laser beam and moving the lens and the object relative to each other along the main surface while adjusting a gap between the lens and the main surface according to the acquired displacement, so as to form the modified region along the line to cut.

2. A laser processing method according to claim 1, wherein the displacement of the main surface along the line to cut is acquired at a first time interval while moving the lens and the object relative to each other at a first speed along the main surface in the displacement acquiring step; and

wherein the modified region is formed while moving the lens and the object relative to each other at a second speed faster than the first speed along the main surface and adjusting the gap between the lens and the main surface at a second time interval shorter than the first

time interval in the processing step.

3. A laser processing method according to claim 1, wherein the displacement acquiring step comprises:

5 a measurement preparatory step of holding the lens at a measurement initial position set such that a converging point of the second laser beam is located at a predetermined position with respect to the object;

10 a first measurement step of starting emitting the second laser beam while holding the lens at the measurement initial position, moving the lens and the object relative to each other along the main surface, and releasing the lens from being held at the measurement initial position in response to reflected light of the second laser beam reflected by the main surface; and

15 a second measurement step of adjusting the gap between the lens and the main surface after the release while detecting the reflected light of the second laser beam reflected by the main surface, so as to acquire the displacement of the main surface along the line to cut.

4. A laser processing method according to claim 1, wherein the processing step comprises:

20 a processing preparatory step of setting a processing initial position for holding the lens with respect to the main surface according to the displacement of the main surface along the line to cut acquired by the displacement acquiring step, and holding the lens at thus set processing initial position;

25 a first processing step of starting emitting the first laser beam while holding the lens at the processing initial position, and moving the

lens and the object relative to each other so as to form the modified region in one end part of the line to cut; and

a second processing step of releasing the lens from being held at the processing initial position after forming the modified region in the one end part of the line to cut, and moving the lens and the object relative to each other after the release while adjusting the gap between the lens and the main surface according to the displacement of the main surface along the line to cut acquired in the displacement acquiring step, so as to form the modified region.

5. A laser processing method according to claim 1, wherein, in the displacement acquiring step, the first laser beam is emitted when acquiring the displacement of the main surface along the line to cut, so as to form the modified region along the line to cut.

6. A laser processing method according to claim 5, wherein the modified region formed in the displacement acquiring step is formed between the modified region formed in the processing step and the main surface.

7. A laser processing method according to claim 1, wherein the line to cut includes first and second lines to cut;

wherein the displacement acquiring step moves the lens relative to the object in a first direction extending along the first line to cut, so as to acquire the displacement of the main surface along the first line to cut, and then moves the lens relative to the object in a second direction opposite from the first direction, so as to acquire the displacement of the main surface along the second line to cut; and

wherein the processing step forms the modified region along the

first line to cut in the first direction, and then forms the modified region along the second line to cut in the second direction.

8. A laser processing apparatus for irradiating an object to be processed with a first laser beam while converging the first laser beam with a lens such that a converging point is positioned within the object, and forming a modified region within the object along a line to cut in the object; the apparatus comprising:

a lens for converging the first laser beam and a second laser beam for measuring a displacement of a main surface of the object onto the object;

displacement acquiring means for acquiring the displacement of the main surface of the object by detecting reflected light reflected by the main surface in response to irradiation with the second laser beam;

moving means for moving the object and the lens relative to each other along the main surface of the object;

holding means for holding the lens such that the lens freely advances and retracts with respect to the main surface; and

control means for controlling respective behaviors of the moving means and holding means;

wherein, while emitting the second laser beam, the control means controls the moving means so as to move the object and the lens relative to each other along the main surface, the displacement acquiring means acquiring the displacement of the main surface along the line to cut; and

wherein, while emitting the first laser beam, the control means controls the holding means so as to hold the lens while adjusting a gap

between the lens and the main surface according to the displacement acquired by the displacement acquiring means, and controls the moving means so as to move the lens and the object relative to each other along the main surface, thereby forming the modified region.

5 9. A laser processing apparatus according to claim 8, wherein, while emitting the second laser beam, the control means controls the moving means so as to move the object and the lens relative to each other along the main surface at a first speed, the displacement acquiring means acquiring the displacement of the main surface along the line to
10 cut at a first time interval; and

 wherein, while emitting the first laser beam, the control means controls the moving means so as to move the lens and the object relative to each other along the main surface at a second speed faster than the first speed, and controls the holding means so as to adjust the gap
15 between the lens and the main surface at a second time interval shorter than the first time interval.

10 10. A laser processing apparatus according to claim 8, wherein the control means controls the holding means so as to hold the lens at a measurement initial position set such that a converging point of the
20 second laser beam is located at a predetermined position with respect to the object;

 wherein, while starting the emission of the second laser beam with the lens being held at the measurement initial position, the control means controls the moving means so as to move the lens and the object
25 relative to each other along the main surface, and controls the holding means so as to release the lens from being held at the measurement

initial position in response to the reflected light of the second laser beam reflected by the main surface; and

wherein, after the release, the control means controls the holding means so as to adjust the gap between the lens and the main surface while detecting the reflected light of the second laser beam reflected by the main surface, the displacement acquiring means acquiring the displacement of the main surface along the line to cut.

11. A laser processing apparatus according to claim 8, wherein the control means controls the holding means so as to set a processing initial position for holding the lens with respect to the main surface according to the displacement of the main surface along the line to cut acquired by the displacement acquiring means, and hold the lens at thus set processing initial position;

wherein, while starting the emission of the first laser beam with the lens being held at the processing initial position, the control means controls the moving means so as to move the lens and the object relative to each other, thereby forming the modified region in one end part of the line to cut; and

wherein, after forming the modified region in the one end part, the control means controls the holding means so as to release the lens from being held at the processing initial position and adjust the gap between the lens and the object according to the displacement of the main surface acquired by the displacement acquiring means, and controls the moving means so as to move the lens and the object relative to each other, thereby forming the modified region.

12. A laser processing apparatus according to claim 8, wherein the

displacement acquiring means emits the first laser beam when acquiring the displacement of the main surface, so as to form the modified region along the line to cut.

13. A laser processing apparatus according to claim 12, wherein the moving means is adapted to move the object toward the lens; and

wherein the control means controls the moving means such that the modified region formed along the line to cut when the displacement acquiring means acquires the displacement is formed between the modified region formed later along the line to cut and the main surface.

14. A laser processing apparatus according to claim 8, wherein the line to cut includes first and second lines to cut;

wherein the control means controls the moving means so as to move the lens relative to the object in a first direction along the first line to cut, while the displacement acquiring means acquires the displacement of the main surface along the first line to cut, and then the control means controls the moving means such that the lens moves relative to the object in a second direction opposite from the first direction, while the displacement acquiring means acquires the displacement of the main surface along the second line to cut; and

wherein, after forming the modified region along the first line to cut in the first direction, the control means controls the moving means so as to form the modified region along the second line to cut in the second direction.